AERONAUTICAL AND ASTRONAUTICAL ENGINEER

FOUNDATION OF A LONG-TERM RESEARCH EFFORT IN LIQUID SPRAY DETONATIONS FOR USE IN A PULSE DETONATION ENGINE

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The pulse detonation engine (PDE) concept, which may provide increased performance for high speed tactical missiles, is reviewed. For the PDE technology to realize its full potential, high-energy-density, liquid-hydrocarbon fuels must be detonated reliably with air. The present project has initiated a long-term effort to characterize critical detonation properties of liquid fuel sprays in air. A modular, stainless-steel detonation tube, and an acrylic replica were designed and built to measure detonation wave and liquid-spray characteristics. Air-assist atomizing nozzles were tested with both qualitative and quantitative diagnostics to characterize forward and reverse-flow injection of water sprays into simulated PDE combustors. Laser-illuminated, stop-action video data recorded poor axial penetration of the injected spray near the head end of the combustor. Malvem 2600 Particle Analyzer data showed Sauter mean diameters between 10 and 60 microns. Laser transmittance and Malvern measurements both indicated that considerable fuel mass was either lost from the open tube end or deposited on the tube wall before the desired detonation time, indicating that improvements are required for the fuel injection process. The transient nature of the injection limited the usefulness of a phase-doppler particle analyzer. Two fuel-injection configurations were characterized with comparable particle mass concentrations, but significantly different levels of homogeneity throughout the detonation tube.

MINIMUM VARIATION MANEUVERS USING INPUT SHAPING AND PULSE-WIDTH, PULSE FREQUENCY MODULATED THRUSTER CONTROL

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Minimizing the modal vibration induced by on-off thrusters is a challenging problem for designers of flexible spacecraft. This thesis presents the first study of Pulse-Width, Pulse-Frequency (PWPF) modulated thruster control using the method of command input shaping. Input shaping for systems with linear actuators has been successfully developed to reduce modal vibrations. Recently, this method has been extended to systems with on-off actuators to some degree. However, existing approaches require complicated non-linear optimization and result in bang-bang control action. Bang-bang thruster operation on flexible spacecraft is propellant-intensive and causes frequent thruster switches. In this thesis, a new approach integrating command input shaping with PWPF-modulated thruster control is developed to minimize residual vibration in maneuvers and to reduce propellant consumption. To realize this approach, an in-depth analysis of the PWPF modulator is first conducted to recommend parameter settings. Next, command input shapers are designed and integrated with the PWPF modulator. Simulation verifies the efficacy of this technique in reducing modal vibration. Lastly, robustness analyses are preformed and demonstrate the method's insensitivity to frequency and damping uncertainty.

AERODYNAMIC ANALYSIS OF A MODIFIED, PYLON-MOUNTED JSOW/CATM USING MULTI-GRID CFD METHODS

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Computational Fluid Dynamics (CFD) has become a major tool in aerodynamic analysis throughout the aerospace industries, complementary to traditional methods such as wind tunnel testing, and analytical calculations. In this research, an attempt was made to integrate the Similarity and Area Rules with CFD methods. Both tools, the Similarity/Area-Rule and CFD are used to derive the characteristics of complicated aerodynamic shapes in the transonic Mach number regime. It was found that the Similarity Rule can only be verified qualitatively. On the other hand, the Area Rule can be more completely verified. The aim was to find ways to minimize the drag of the training configurations of the Air-to Ground (A/G) weapon, Joint-Standoff-Weapon (JSOW), in its Captive-Air-Training-Missile (CATM) configuration. By analyzing the combination of CATM and Pylon, it was found that the drag of this configurations depends on the average slop of the area cross-section distribution of the afterbody. The CFD tools used were state-of-the-art grid generation code GRIDGEN, and multi-grid integration code PEGSUS; the configurations were run with the OVERFLOW solver using Euler, as well as Navier-Stokes solutions. For drag optimization, Euler solutions give adequate results, the need for NS solution can be restricted to more intensity viscous analysis.

MODELING AND ANALYSIS OF HELICOPTER GROUND RESONANCE UTILIZING SYMBOLIC PROCESSING AND DYNAMIC SIMULATION SOFTWARE

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This thesis develops a technique for formulating the full nonlinear equations of motion for a coupled rotor-fuselage system utilizing the symbolic processing software MAPLE®. The symbolic software is further utilized to automatically convert the equations of motion into C, Fortran or MATLAB® source code formatted specifically for numerical integration. The compiled source code can be accessed and numerically integrated by the dynamic simulation software SIMULINK®. SIMULINK® is utilized to generate time history plots of blade and fuselage motion. These time traces can be used to explore the effects of damping nonlinearities, structural nonlinearities, active control, individual blade control, and damper failure on ground resonance. In addition, a MATLAB® program was developed to apply the Moving Block Technique for determining modal damping of the rotor-fuselage system from the time marching solutions.

ACTIVE VIBRATION CONTROL OF FLEXIBLE STRUCTURES USING THE MODULAR CONTROL PATCH (MCP)

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Active vibration control has been increasingly used as a solution for spacecraft structures to achieve the degree of vibration suppression required for precision pointing accuracy that is not easily achieved with passive damping. This thesis examines the effectiveness and suitability of the Modular Control Patch (MCP) to achieve active vibration control on flexible struc-

tures. The MCP was developed by TRW for the United States Air Force and uses a digital signal processor to implement control algorithms. The objective of the MCP program was to design a miniaturized multi-channel digital controller suitable for space-based vibration control. Three different control laws: Positive Position Feedback (PPF), Strain Rate Feedback (SRF), and Integral control were realized using the MCP. These control laws were used independently and in combination in order to discover the most effective damping for the first two modal frequencies on a cantilevered aluminum beam. Two PPF filters in parallel provided the most effective mulit-mode damping. Further experiments tested the robustness of the PPF control law implemented by the MCP. Increasing the compensator damping greatly improved PPF robustness and expanded its capability as an effective controller.